STATE OF VERMONT
PUBLIC SERVICE BOARD

Docket No. 6860

Petitions of Vermont Electric Power Company, Inc. and Green Mountain Power Corporation for a Certificate of Public Good authorizing VELCO to construct the so-called Northwest Vermont Reliability Project, said project to include: (1) upgrades at 12 existing VELCO and GMP substations located in Charlotte, Essex, Hartford, New Haven, North Ferrisburg, Poultney, Shelburne, South Burlington, Vergennes, West Rutland, Williamstown, and Williston, Vermont; (2) the construction of a new 345 kV transmission line from West Rutland to New Haven; (3) the construction of a 115 kV transmission line to replace a 34.5 kV and 46 kV transmission line from New Haven to South Burlington; and (4) the reconductoring of a 115 kV transmission line from Williamstown, to Barre, Vermont

PREFILED SURREBUTTAL TESTIMONY OF
JAY WILLIAMS
ON BEHALF OF THE
VERMONT DEPARTMENT OF PUBLIC SERVICE

September 3, 2004

Summary: The purpose of Mr. Williams' testimony is to respond to testimony offered in rebuttal by Jean Vissering concerning burial of 345 kV line and by Torben Aabo regarding automatic reclosure and the 115 kV line configuration used by the Vermont Department of Health.

Prefiled Surrebuttal Testimony
of
Jay Williams

Q. Please state your name, occupation, and place of employment.

A. My name is Jay Williams. I am a principal engineer with Power Delivery Consultants, Inc., with a business address at 28 Lundy Lane, Ballston Lake, NY 12019.

Q. Please describe your educational background and experience.

A. I earned the Bachelor of Science degree in engineering from Brown University and an MBA from New York University. I worked as a cable engineer at Con Edison from 1965 until 1973, and was in charge of the transmission cable group there when Con Edison was installing major amounts of 345-kV cable. I worked at Power Technologies, Inc. from 1973 until 1992 and was in charge of the cable group when I left in 1992 to form Power Delivery Consultants, Inc. with another cable specialist. At PDC I head a group of engineers including five engineers who spend essentially full time on transmission cable systems. I have developed and present several courses each year on underground power transmission, and have written more than fifty technical papers, articles, and book sections on underground transmission cables. I am a Fellow of the IEEE and a registered Professional Engineer in New York and Ohio. My resume is attached as Exhibit DPS-JW-1.

I testified as an expert witness on behalf of the Vermont DPS for the cable crossing at Grand Isle as part of the PV-20 line application, and have testified as a cable expert for several utilities evaluating underground transmission lines. I am currently assisting Northeast Utilities as its expert witness on cable systems for major 345-kV installations as part of the Southwest Connecticut Reliability Project.

Q. What is the purpose of your testimony?

A. My testimony responds to testimony offered in rebuttal by Jean Vissering concerning burial of 345 kV line and by Torben Aabo regarding automatic reclosure and the 115 kV line configuration used by the Vermont Department of Health.

Q. Jean Vissering's rebuttal testimony on behalf of the Addison County Regional Planning Commission recommends, starting on page six, answer 12, that the Public Service Board consider burial of the proposed 345 kV line at two sites, one each in Salisbury and Middlebury, Vermont. Please briefly define and describe the basic underground cable construction options available for burying 345 kV lines.

A. Four underground cable system types have been used commercially at 345 kV and higher.

High-pressure Fluid-filled (HPFF) cable accounts for almost all of the 345-kV cable in this country. The conductors are insulated with wrapped layers of paper tape that are factory impregnated with a dielectric liquid, are shipped to the site on large reels and all three phases pulled at one time into a previously installed 8.625-inch OD coated and cathodically protected steel pipe. The line is filled with a dielectric liquid that is pressurized to 200-250 psig. At least one pressurizing plant is installed to maintain this pressure while accepting fluid expansion and contraction.

Self-contained Fluid-filled (SCFF) cables are also paper-insulated. Hollow-core conductors are insulated with wrapped paper tapes that are factory impregnated with a dielectric fluid, and a lead or aluminum sheath is applied. Reservoirs spaced every mile or two maintain 15-50 psi fluid pressure. The individual phases are installed in duct, or directly buried. SCFF cable has been installed at 500 kV and has been tested at 345 kV, but there are no 345-kV SCFF cables installed in this country. Its use is diminishing worldwide in favor of XLPE-insulated cables.

Cross-linked Polyethylene (XLPE)-insulated cables have the conductors insulated with polyethylene, which is extruded over the conductors then cross-linked at high temperatures. A lead, aluminum, or copper sheath is applied, and the individual conductors are pulled into ducts or directly buried. There are only short, splice-free 345-kV lines in this country, but there are significant lengths installed at 345-kV and higher voltages overseas, and there are significant lengths installed at 230 kV in the United States.

Gas-insulated Lines (GIL) resemble substation bus, having tubular rigid aluminum conductors held centered in rigid aluminum enclosures by spacers. There are a few buried lines, but these systems are generally installed above ground in substations, and they are very costly.

Q. With respect to the line burial in Salisbury, Vermont, on cross-examination Ms. Vissering stated that she would recommend that the Board consider requiring burial of approximately a mile-and-a-half of the proposed 345 kV line. 7/29/04 tr., Vol. 1 at 44-5. Please provide your estimate of the approximate cost of burying that length of 345 kV line. In so doing, please describe the configuration you used and state any important assumptions made in reaching that estimate.

A. I prepared a brief, conceptual design of a potential cable system. The conceptual design assumes XLPE-insulated cables for all of the potential applications. This cable type does not contain dielectric liquid, does not require pressurizing plants, has simpler accessories, requires smaller transition stations, and requires less maintenance than HPFF cable. XLPE cable is generally less costly than HPFF cable, especially for shorter lengths where the transition station costs dominate.

My estimate of the cost for an underground 345-kV line in Salisbury is approximately $9.8 million for a system rated 1500 MVA and $6.8 million for a system rated 500 MVA, the two power levels the DPS requested me to evaluate. This estimate is based upon the following assumptions:

1500 MVA system: 345-kV XLPE-insulated cables, two cables per phase to meet the power transfer requirement, 1750 kcmil segmental copper conductor, installed in a two wide by three high concrete-encased ductbank, with nominal 8-inch diameter ducts and 36-inch cover to the top of the ductbank to permit farming activities. Four splices installed per cable. One road crossing. Transition stations installed at each end.

500 MVA system: 345-kV XLPE-insulated cables, one cable per phase with a fourth, spare cable; 1500 kcmil segmental copper conductor, installed in a two wide by

two high square ductbank, with nominal 8-inch diameter ducts. Four splices installed per cable. One road crossing. Transition stations installed at each end. The fourth, spare cable is installed because it is unlikely that a 345-kV system could tolerate the outage time – which could be a month or longer – to repair a failed cable if only three cables were installed.

The transition stations are a minimal design corresponding to the pole-mounted terminations on a 115-kV XLPE cable system, and conceptually would consist of fenced areas, a minimum 75 by 75 feet, requiring road access and requiring connection of alarms for the fluid levels in the terminations. Typically, a deadend structure would be installed on the overhead line, and leads installed to connect to the terminations that would be installed on substation-type structures in the station. Lightning arresters and removable links would be installed. These stations are large and could be difficult to site.

The Salisbury location includes wetlands, and may flood in the spring; it also may include archeologically significant areas. My cost estimate does not include directional drilling or any other expensive methods to account for the wetlands or potential archeological sites. Detailed design would have to address site-specific concerns.

Q. With respect to the line burial in Middlebury, Vermont, on cross-examination Ms. Vissering stated that she would recommend that the Board consider requiring burial of approximately one half mile of the proposed 345 kV line. 7/29/04 tr., Vol. 1 at 45. Please provide your estimate of the approximate cost of burying that length of 345 kV line. In so doing, please describe the configuration you used and state any important assumptions made in reaching that estimate.

A. My estimate of the cost is approximately $5.1 million for a system rated 1500 MVA and $4.1 million for a system rated 500 MVA. This estimate is based upon the following conceptual design:

1500 MVA system: 345-kV XLPE-insulated conductors, two cables per phase, 1750 kcmil segmental copper conductor, installed in a two wide by three high concrete-encased ductbank, with nominal 8-inch diameter ducts. One splice installed per cable. One road crossing. Transition stations installed at each end.

500 MVA system: 345-kV XLPE-insulated cables, one cable per phase with a fourth, spare cable, 1500 kcmil segmental copper conductor, installed in a two wide by two high square concrete-encased ductbank, with nominal 8-inch diameter ducts. One splice installed per cable. One road crossing. Transition stations installed at each end.

This area is also wet, may contain archeologically-significant sites, and Route 7 is a busy road. This would be a likely candidate for a directional drill, and my costing assumed using a directional drill.

For these potential applications, an all-duct system is more appropriate, because of the critical nature of the circuit and the desire to minimize potential outages. It might be feasible to install the cables directly buried except for the road crossings which would be in duct. Concrete slabs would be placed above the direct buried cables to provide mechanical protection. Directly buried cables would be less costly, but repair time would generally take longer because of the need to locate, excavate, and repair a failed cable, versus replacing a manhole-to-manhole section for an all-duct system.

Q. With respect to Ms. Vissering's recommendation in her rebuttal testimony on behalf of the ACRPC, at page six, answer 12, that the Public Service Board consider burial of the proposed 345 kV line, please briefly comment on the reliability of a buried 345 kV line using a 4-cable XLPE configuration.

A. Failure of a cable section or a splice can take a month or longer to repair; that outage time is generally considered too long for a major 345-kV transmission line and almost always represents an unacceptable solution. Installing a fourth conductor the full length, splicing and terminating the conductor, and making advance provisions for connecting it to replace a failed phase, will permit restoring the line to service quickly, within an 8-hour period. The line can then operate at full capacity until a scheduled outage can be taken to repair the failed cable or splice.

This approach would be feasible for the 500 MVA case. A single line cannot carry 1500 MVA; therefore two lines (two cables per phase) would be required for that case, and power transfer would be limited to somewhat more than 750 MVA if one line were out of service for a month. If one cable failed, it would take the utility as long as eight hours to identify the failed cable, remove that line from service, and re-energize the unfailed line. This time could be reduced by installing monitoring equipment and disconnects, but my conceptual design and cost only considered removable links.

The foregoing assumes use of ducts. A directly-buried cable failure would probably take longer than a month to repair, especially in wetland areas where access would be difficult.

Q. Please state the reason for your use of an XLPE configuration for your conceptual design and estimates.

A. In my opinion, there is sufficient experience with 345-kV and higher voltage XLPE-insulated cable systems in this country and overseas to justify using this cable type, especially in view of the advantages described earlier. Some utilities permit farming activities over cable systems as long as there is no chance of damaging the cables. Although it might be feasible to install the cables directly buried with a concrete cap in the farmland area, using ducts will provide additional mechanical protection and allow for more rapid cable replacement if needed. Although the utility industry is gaining confidence in 345-kV XLPE-insulated cables, these EHV cables have only been installed in this country for three years, and overseas for seven years. If it turns out that replacement is needed, having a duct system in place will greatly speed the replacement process and reduce the cost. The fourth cable for the 500-MVA case permits returning the line to service within eight hours if there were a failure.

Q. In his prefiled rebuttal testimony on behalf of the Towns of Charlotte and Shelburne, Torben Aabo testifies that "some utilities that operate hybrid transmission lines have a practice of allowing one reclosure." Aabo, reb. at 1, answer three. Please state the general practice in the electric utility industry with respect to allowing one reclosure on non-radial hybrid transmission lines.

A. Yes, some utilities do allow one reclosure on a 115-kV XLPE-insulated cable line that has an adequately sized shield/sheath assembly and proper bonding and grounding connections, and where the cable section is a small percentage of total line length, for example a 500-foot section as a dip for an airport runway in a 10-mile overhead line. A small percentage should be viewed as under a few percent of line length. In the proposed Vermont 115 kV undergrounding, approximately 33% of the segment is proposed to be undergrounded and this exceeds the reasonable limits. Utilities have ongoing concerns about manhole covers lifting during faults; a reclosing would increase that possibility – and the gases developed during the first fault might make the amount of released energy greater during the reclosing.

There is very little experience with 345-kV XLPE-insulated cables in this country; reclosing on this voltage cable is not recommended at all until we gain more experience with operating XLPE-insulated cables at this voltage.

Q. In his prefiled rebuttal testimony on behalf of the Towns of Charlotte and Shelburne, Torben Aabo testifies that "some utilities that operate hybrid transmission lines have a practice of allowing one reclosure." Aabo, reb. at 1, answer three. Why would a utility have such a practice?

A. Ideally, the utility would not reclose until a full investigation had been made to insure the trip was not due to a cable failure. However, on a line where the underground portion is a small percentage of the length, most trips are likely to be self-clearing faults on the overhead sections, and the utility would take the risk of one reclosing. Fault currents flowing through the cable for one reclosing should not damage the cable if the cable system were properly designed, installed, and maintained. The utility is therefore willing to take the small risk of damaging the cable, and the utility would consider restraining the manhole covers if the line is in a populated area.

Q. In his prefiled rebuttal testimony on behalf of the Towns of Charlotte and Shelburne, Torben Aabo testifies that "some utilities that operate hybrid transmission lines have a practice of allowing one reclosure." Aabo, reb. at 1, answer three. In your opinion, should such a practice be applied to the proposal to bury, as you say, approximately 33 percent of VELCO's proposed 115 kV line?

A. No. As mentioned above, there are risks associated with reclosure, and I would not recommend reclosing on a cable line of the proposed lengths, especially if portions are in populated areas. Since the Vermont project would not be a good application for reclosing a circuit, every time the line trips, it would be necessary to investigate the cause and insure the failure was not in the cable section, before reclosing.

To be clear, if the underground portion is a small percentage of the line length, e.g. 500 feet in ten miles as described above for a 115-kV system, and if the cable shield/sheath bonding system is adequately sized, and if it were certain that the controls in the substations would permit only one reclosing, I would allow one reclosing unless the line had manholes located in populated areas.

I would like to note that on two occasions where my firm was involved in failure analysis, there was more than one reclosing, and the lines failed apparently as a result. So the risk is very real. If the underground sections were a significant length – more than a half mile – or in a populated area, I would not recommend reclosing unless reliable relaying were present to verify that the failure was not in the cable section. This relaying requires current transformers, potential transformers, reliable communications, a power supply and a small enclosure to house the equipment, at every transition. Further, this equipment and enclosure must be placed within a fenced-in area at every transition that does not already occur within a substation. The simple transition structure that otherwise could be used for a 115-kV line would not be appropriate for this application.

Q. When examined by the Board during the rebuttal hearings, Mr. Aabo stated that the following "seems to be unreasonable" (7/29/04 tr., Vol. 2 at 225): the use by the Vermont Department of Health of a six-inch distance from grade to the top of the duct bank in one scenario for burying 115 kV line. Do National Electric Safety Code requirements allow burial of a 115 kV line with a six-inch distance from the top of the duct bank to grade?

A. The NESC permits shallow depths where sufficient supplemental mechanical protection is provided. Six inches is unusually shallow and would only be used if there were no other reasonable options. However, with proper mechanical protection in addition to the concrete of the ductbank itself, I do not believe the 6-inch depth would violate the NESC.

Q. On redirect examination during rebuttal hearings, Mr. Aabo testified that he used a horizontal duct bank configuration and contrasted this configuration to a two-by-two square duct bank configuration used by the Vermont Department of Health, stating that the horizontal configuration “would potentially lower the EMF some, not much.” 7/29/04 tr., Vol. 2 at 232. Which configuration would you expect to produce lower EMFs, the horizontal configuration or the square duct bank configuration?

A. I would expect the square duct bank configuration to have a lower magnetic field.

Q. Please state the reason for your answer to the immediately preceding question.

A. The square duct bank configuration will have the cables more closely approximating a triangular configuration, which is the configuration that gives the lowest magnetic field. Calculations and measurements that PDC has performed for the Electric Power Research Institute show that a horizontal configuration can have a magnetic field almost 50 percent greater than a square duct bank configuration.

Q. Does that conclude your testimony?

A. Yes, it does.